DOE/NV/25946--235

Personal Radiation Detector Field Test and Evaluation Campaign

Chris A. Hodge, Ding Yuan, and
Raymond P. Keegan
Remote Sensing Laboratory
National Security Technologies, LLC
P.O. Box 98521, MS RSL-44,
Las Vegas, NV 89193

Michael A. Krstich
Department of Homeland Security
Domestic Nuclear Detection Office,
Assessments Directorate
245 Murray Lane, Bldg 410, MS 7100,
Washington, DC 20528

ABSTRACT

Following the success of the Anole[1] test of portable detection system, the U.S. Department of Homeland Security (DHS) Domestic Nuclear Detection Office organized a test and evaluation campaign for personal radiation detectors (PRDs), also known as “Pagers”. This test, “Bobcat”, was conducted from July 17 to August 8, 2006, at the Nevada Test Site. The Bobcat test was designed to evaluate the performance of PRDs under various operational scenarios, such as pedestrian surveying, mobile surveying, cargo container screening, and pedestrian chokepoint monitoring. Under these testing scenarios, many operational characteristics of the PRDs, such as gamma and neutron sensitivities, positive detection and false alarm rates, response delay times, minimum detectable activities, and source localization errors, were analyzed. This paper will present the design, execution, and methodologies used to test this equipment for the DHS.

INTRODUCTION

The U.S. Department of Homeland Security (DHS) Domestic Nuclear Detection Office (DNDO) sponsored testing, named Bobcat, of Personal Radiation Detectors (PRDs) at the National Nuclear Security Administration’s Nevada Test Site (NTS) as a Work for Others effort through the National Nuclear Security Administration. The goals of the Bobcat test[2,3] were to test the effectiveness of:

- PRDs in detecting threat radionuclide in pedestrian surveying operations
- PRDs in detecting threat radionuclide in mobile surveying operations
- PRDs in detecting and localizing threat radionuclide in screening operations
- Identification (ID)-capable PRDs in identifying and discriminating threat and nuisance radionuclide in screening operations
- PRDs in detecting threat radionuclide in pedestrian chokepoint monitoring operations
- PRDs in setting an exclusion area in support of personal safety considerations

TEST DESIGN

TEST SCENARIOS

PEDESTRIAN SURVEY (SCENARIO 1)

In the pedestrian survey, the PRD was placed on the operator's body as would be done while performing normal foot patrols. The PRD was placed at one of three locations on the body: on the hip near the source, on the hip away from the source, or on the chest. Two straight operator walk-paths were marked on the ground past the sources using tape marked in feet at perpendicular distances (1 and 3m) from the source. Two PRDs were tested for each model. The main technical objectives are the effectiveness and the consistency of the radioactive source detection. Figure 1 shows the layout of the test track for scenario 1 and Figure 2 shows the actual performance testing. The tablet operator would record: 1) Distance (d_3-G) from start at which the first gamma alarm sounds; 2) Distance (d_3-N) from start at which the first neutron alarm sounds; 3) Distance from start at which the last gamma alarm ends (d_5-G); 4) Distance (d_5-N) from start at which the last neutron alarm ends; 5) Indicator of multiple gamma alarms (Y/N); and 6) Indicator of multiple neutron alarms (Y/N).

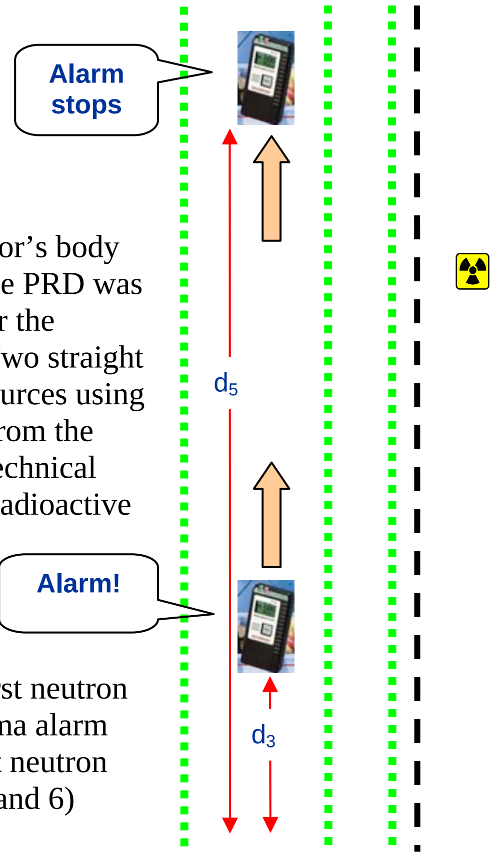
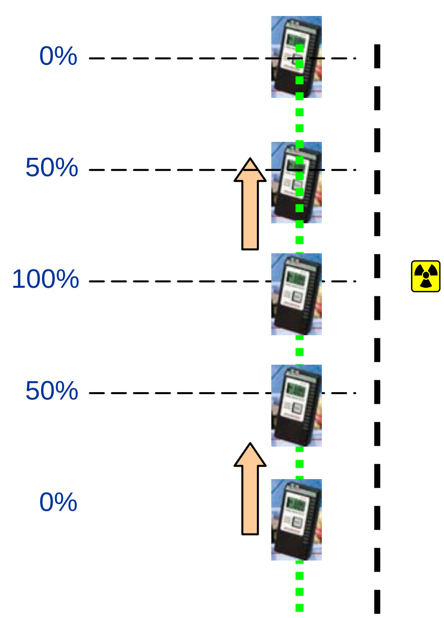


Figure 1 – Schematic of Scenario 1 – Pedestrian Surveys

PEDESTRIAN SURVEY (SCENARIO 1A)

The setup of Scenario 1A is the same as that for Scenario 1 except that a single source was used for this test. The tablet operator recorded: The exposure rate at the defined start point (10 feet in front of the source); 2) The exposure rate at the 5-foot point (50% distance) before the source; 3) The exposure rate at the perpendicular point; 4) The exposure rate at the 5-foot point (50% distance) past the source; and 5) The exposure rate at the defined end point (10 feet past the source). Figure 3 shows the track layout for this scenario.

Figure 2 – Pedestrian Surveys: Walking the Track. DNOD observer (l), Tablet Operator (m), PRD Operator (r).



– Figure 3 – Schematic of Scenario 1a

MOBILE SURVEY (SCENARIO 2)

Scenario 2, schematically shown in Figure 5, is a simulation of a mobile survey using a PRD inside a patrol vehicle as it performs normal road patrols. Three 15-passenger vans were used for this test and the 15 PRDs were distributed between the vans allowing the PRDs to be tested simultaneously. Figure 5 is a photograph at the actual test.

As Figure 6 shows, the PRDs were mounted on the passenger side windows of each vehicle (plastic shower caddies were used to hold the PRDs) and oriented so that the PRD operator sitting in the adjacent seat could read them.

Three vans were driven past one source at 5 and then at 25 mph. A full data set was collected for the first copy of a given PRD model before proceeding to the next copy of that model. The major objective of this scenario was to test the effectiveness and consistency of the radioactive source detection with a PRD in a moving vehicle. The test results can be additionally used for assessing performance as a function of vehicle speed during mobile survey operations. Recorded Results were: 1) the type of alarm sounded (e.g., gamma, neutron, none), and 2) the maximum exposure/count rate reading.

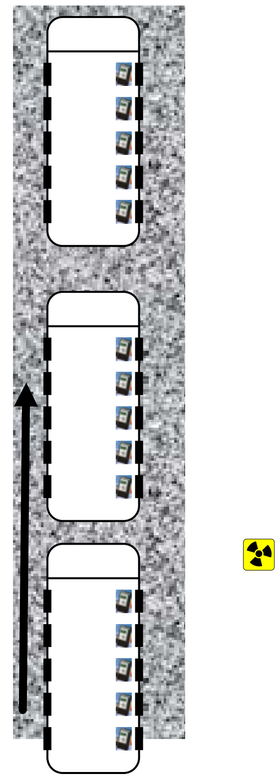


Figure 4 – Schematic of Scenario 2 – Mobile Surveys

Figure 5 – Scenario 2 - Mobile Surveys

Figure 6 – Mobile Surveys; PRD Orientation

SCREENING (SCENARIO 3A)

Scenario 3A is a simulation of an everyday operation where an operator uses a hand-held PRD to locate a source upon a self-cue (own alarm) or an external cue (somebody else's alarm or indication). The goal is to locate the source; not to identify it. The setup of this scenario for a single Container Express (CONEX) shipping container as Figure 7 shows. It involves the placement of sources inside the CONEXs. The CONEXs were lined up on the ground about 40 feet apart, but

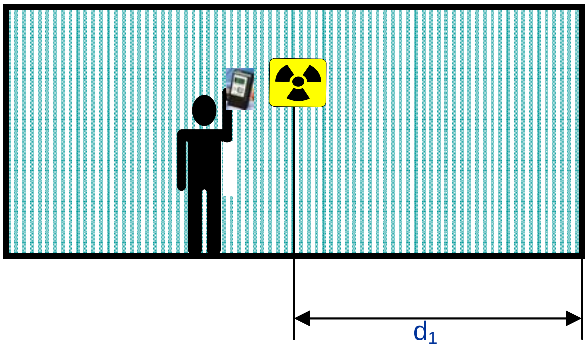


Figure 7 – Schematic of Scenario 3

angled at about 45º to each other so that one PRD operator could not see the other. CONEXs contained 17,000kg of Naturally Occurring Radioactive Material (NORM), 1 inch of steel and 12 inches of plywood as shielding material, or no shielding. The sources were placed in the CONEXs along the midline at 1*m* height.

The PRD operator held the PRD in hand and walked in one direction along the side of the CONEX, surveying along a line marked on the outside of the CONEX on the plane of the source. The point where the source was located was determined by observing where the gross count rate was the greatest. The maximum time allocated to the PRD operator to locate was 2 minutes.

Depending on the exposure/count rate, the PRD may or may not have set off the alarm during this operation.

The maximum exposure/count rate for gamma and neutrons, if available, was recorded with the start and stop times. The tablet operator stood by the CONEX and recorded the results. The PRD operator moved onto the next CONEX as shown in Figure 8. The results recorded were: 1) the observed horizontal location of the source; 2) the gamma exposure rate at identified location; 3) the neutron count rate at identified location; and 4) the start and stop time.

Figure 8 -– Photograph of Scenario 3a Testing

SCREENING IDENTIFICATION (SCENARIO 3B)

In scenario 3B, the operator used a PRD with identification capability to identify a source after localization. The Thermo Electron Interceptor was the only PRD with this capability. The sources were arranged within the CONEXs using the same configuration as in Scenario 3A (see Figure 7). The PRD operator placed the PRD on the point on the side of the CONEX closest to the source and was given up to 30 minutes to perform the identification. Spectra were extracted from the PRD and provided for inclusion into the Bobcat database. The technical objective of this scenario was to assess the effectiveness of the PRD in identifying threat radionuclide and naturally occurring radionuclide during screening operations. The data recorded included: 1) the recorded spectra as applicable; 2) the displayed choice of radioisotopes from the PRD library list; 3) the maximum exposure/count rate reading (gamma and neutron as applicable); and 4) the start and stop time.

CHOKEPOINT MONITORING (SCENARIO 4)

In scenario 4, a PRD is used to monitor the passage of people. The operator stands at a pedestrian chokepoint while the concealed source on a person moves toward the operator in a crowd of people (see Figure 9). In a regular operational environment, the operator would wear the PRD on the hip facing the pedestrian line and, therefore, the source.

A source was placed in a backpack and the backpack carrier walked through the chokepoint in a line of 11 other backpack carriers with similar source-free backpacks. Figure 10 shows backpack carriers walking through the chokepoint.

Only one of the carriers had a source, and in some of the runs no carrier had a source. The PRDs were located on the front of the operators to facilitate monitoring of the instrument while watching the carriers. In this scenario, the PRD operators were also tablet operators and recorded their own results. data recorded: 1) the type of alarm that sounded (gamma, neutron, balance, low-energy); 2) the carrier number directly in front of the operator when measured exposure rate begins to decline, indicating that the peak has just passed; and 3) the maximum exposure/count rate.

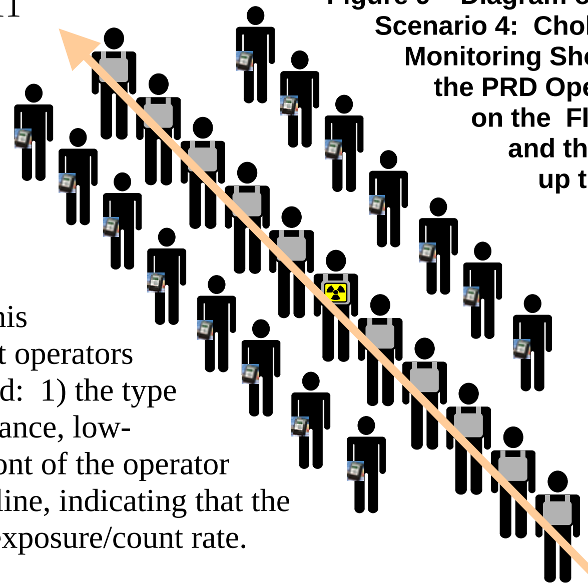


Figure 9 – Diagram of Scenario 4: Chokepoint Monitoring Showing the PRD Operators on the Flanks and the Subjects up the Middle.

Figure 10 – Scenario 4: Pedestrian Chokepoint Monitoring.

PERSONAL SAFETY CONSIDERATIONS (SCENARIO 5)

For this scenario, an operator used a handheld PRD to determine the safety exclusion area around a source for a given predetermined exposure rate limit. The PRD operator held the device in front of the body and walked toward a source while observing the exposure rate reading. The PRD operator stopped when the PRD displayed the predetermined exposure rate for the exclusion area.

In this simulation, the operators walked toward the source simultaneously from two directions (see Figure 11).

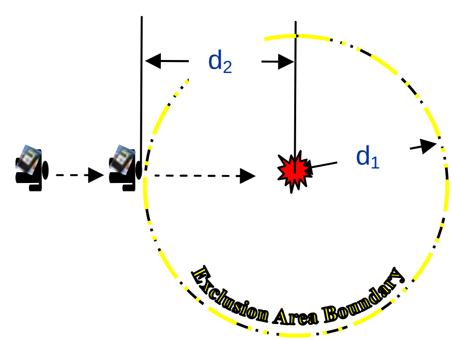


Figure 11: Scenario 5—Personal Safety

In practice, the two paths were 180° apart (also called the 12 and 6 o'clock positions), so that two PRDs were tested simultaneously.

In this simulation, the operators walked toward the source simultaneously from two directions (see Figure 11).

Figure 11 shows a circular exclusion area of radius d_1 from the location of the source located at the center. The exclusion area boundary was preset using a calibrated ion chamber instrument. The PRD operators were not told the true position of the 2*mR/hr* point. The distance d_2 is the exclusion area determined by the PRDs. Ideally, d_1 and d_2 would be the same. For this scenario, the exclusion area was set at 2*mR/hr*. The objective of this test was to assess the effectiveness and the consistency of each model of the PRD in setting up an exclusion area in support of personal safety considerations. The distance from the source at the 2*mR/hr* reading was recorded.

TEST ARTICLES

Fifteen modes of PRDs were tested during this campaign. PRDs are pager-sized instruments that incorporate a gamma detector (many models also have a neutron detector).

PRDs are worn on the body (hip or chest) as a uniform accessory, clear of obstruction from heavy metal accessories, especially weapons. They set off an alarm when a gamma or neutron radiation field exceeds a preset threshold indicating the presence of a radiation source. The alarm may be audible, visual, vibrating, or a combination of these modes. PRDs can be used to warn the user when radiation levels present a safety concern. Some PRDs have radionuclide identification capability.

Nine vendors participated in Bobcat. Together, these vendors provided 20 PRD models for testing. 15 were chosen for testing.

SOURCE MATERIAL

Source materials were chosen to establish performance relative to select threat objects and typical sources found in the stream of commerce. Sources were often combined to test against specific masking or shielding scenarios. For example, medical, industrial, and SNM sources were often placed in and around NORM material to test the instruments ability to discriminate between the two sources. Examples of these sources are:

- Medical sources
  - ^{131}I, ^{99m}Tc
- Industrial Sources
  - ^{241}Am, ^{60}Co, ^{137}Cs/AmBe, ^{192}Ir
- SNM
  - HEU, Pu, DU
- Naturally Occurring Radioactive Material (NORM)
  - Cat litter, roofing tiles, fertilizer

QUALITY ASSURANCE

There were several aspects of quality assurance and quality control that were addressed to assure data integrity. All instrumentation was accepted and tested using American National Standards Institute (ANSI) criteria[4,5,6]. All operators, instrumentation and data collectors were trained, tested, and certified against written procedures to assure minimal performance and level of understanding.

An HPGe spectrum was collected for each unique configuration. Not only was this used to assure configuration control and documentation, but it also served as a comparison for the limiting performance of any of the test articles. Daily background measurements were also obtained with the same HPGe system to document ambient background and its possible fluctuations.

Along with database control of testing and configurations, photo-documentation was obtained on testing and on all unique configurations (see configuration control for additional details).

Quality control (QC) engineers performed a statistical review of acquired data. These engineers selected a few representative cases and tracked the data from the point of raw data collection in the field all the way through the final report to assure data integrity during collection, recording, and reduction.

Figure 12 -- Collection of Configuration HPGe "Ground Truth"

The database contains numerous QC checks to prevent erroneous data entry, such as drop-down menus to limit possible input to only known values. The database also performed several logical checks to assure accurate raw data input. Where possible information (source, NORM, configuration, instrument, operation ID, etc.) was input via bar code to assure accurate data input. All configurations were independently verified by multiple personnel against a pre-written schedule. In most cases, data was scrutinized for consistency (e.g. operators entered the appropriate speed) prior to the commencement of the next test.

SOURCE CONFIGURATIONS

Configurations were selected to establish performance relative to select cargo configurations found in the stream of commerce. Configuration control was maintained by test scientists using the database controls described above, photo-documentation (Figure 13), and required the collaboration of multiple test scientists. The specific test scenarios are described later in this paper. There were nine test configurations for scenario 1, six for scenario 2, six for scenario 3, five for scenario 4, and one for scenario 5.

Variation in the configurations included differing sources, differing source position for location scenarios, differing source/masks combinations (e.g., Pu with NORM), different shielding combinations (e.g., U surrounded by 1” steel), speed for mobile and portal testing, and detector-to-source distance.

Figure 13 – Example of Configuration Photo-Documentation Showing HP Measurements, Distance Documentation, and Source Configuration.

DATA COLLECTION

Figure 14 – Barcode scanning of a PRD during Typical Data Recording

Data were recorded in near real-time with the use of dedicated portable tablet computers and tablet operators. The data collection software employed drop-down menus and fill out tables to allow for faster, more accurate, and more consistent recording of data. Bar code readers were used for identification of test case, instrument, and operator to speed the process and minimize input errors.

Tablet operators and instrument operators were required to verbally verify all data prior to submission. The data was then immediately downloaded via WiFi link where software used a set of rules to check on data integrity and accuracy prior to allowing the operator to continue.

Test case configuration data were also input using a tablet computer. Upon completing the setup of a specific test case, the test coordinator would choose the predetermined test case identification and enter the data associated with NORM, CONEX, source, source position, data documentation photos, and "ground truth" HPGe spectra. Instrument operators would complete their data acquisition through a series of questions and confirmatory read-backs of information (see Figure 13).

CONCLUSIONS

The Bobcat test quantified and documented the following results:

- Conclusions should focus on what the successful design and execution of a complex test campaign that evaluated a broad range and large number of systems.
- Report provided to Federal, State, and local emergency responders (to be available on the Responder Knowledge Base website to qualified individuals).
- Participating vendors received summary of performance of their individual system to aid system improvement.
- Results used to guide development of performance specification of next generation hand-held radiation detection systems being.

When choosing instruments for radiation detection, the Bobcat test campaign has demonstrated that the instruments' primary use needs to be well defined.

REFERENCES

1. "Anole Results of Testing Portables". Chris Hodge, Bechtel Nevada – Remote Sensing Laboratory, 2006.
2. "Test Plan for Personal Radiation Detectors", DHS Document Number 101500V0.08, June 6, 2006.
3. U.S. Customs and Border Protection Radiation Detection Program Directive, CBP Directive No. 5290-015.
4. American National Standards Institute (ANSI) Performance Criteria for Hand-held Instruments for the Detection and Identification of Radionuclides, ANSI N42.34.
5. ANSI Portable Radiation Detection Instrumentation for Homeland Security, ANSI N42.33-2003.
6. ANSI Performance Criteria for Mobile and Transportable Radiation Monitors used for Homeland Security, ANSI N42.43-2006.